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The Rise of the Alkali in the San Joaquin Valley.

The rapid increase of population and settlements in the San Joaquin valley, and the frequency with which inquiries relative to the nature and treatment of "alkali" come to this station from that section as well as other portions of the State, render it expedient to give a summary statement of the main points in the form of a bulletin. A more elaborate treatise on the same subject, originally published in the report for 1880, has been reprinted and can still be sent to those desiring more detailed information.

It is well known that like all regions having a deficient rainfall and requiring irrigation for successful agriculture, the San Joaquin valley has (particularly in its upper portions) tracts of land afflicted more or less with "alkali," that is, showing during the dry season a "blooming-out" of soluble salts on the surface of the ground. This phenomenon is the direct and inevitable result of a scanty rainfall in all regions having a naturally productive soil, from which the mineral matters required for the nutrition of plants are being continually set free by the natural processes included under the general term of *weathering*; a decomposition of the minerals contained in the soil, among the products of which are always the soluble salts of the alkalies (potash and soda). The potash salts are, by a peculiar chemical action, mostly retained in the soil and form an important part of the mineral food of plants; while the soda (or sodium) salts, upon which the soil exerts but a very slight retentive action, are in climates having an abundant rainfall washed currently

into the country drainage and thence into the ocean, whose briny waters testify of the long-maintained accumulative process.

Where the rainfall is scanty, and especially where the showers falling at any one time are so light as to wet the soil only to the depth of a few feet, this current washing-out cannot occur, and the sodium salts necessarily accumulate in the soil together with those of potash, lime and magnesia which are, in the ordinary course of events, wholly or in great part retained by the soil. As a consequence, each time that the soil moisture evaporates between showers, it carries with it to the surface, in solution, whatever of soluble alkali salts may have accumulated within the depth to which it penetrated, to be again washed down by the next shower, to such depth as its amount may justify. This process is in the natural course of events indefinitely repeated with one and the same quantity of alkali salts, diminished only to the extent to which some heavier shower may wash part of the surface accumulation to the lower ground. Hence the latter will as a rule show a larger proportion of alkali on this account alone; in addition, being naturally richer in the fine and easily decomposable mineral powder carried down and deposited by the streams, the low ground will tend to develop proportionally more alkali than the higher land; and thus we often find such lands, and even the river bottoms, heavily incrustated, when the adjacent uplands are practically free from alkali. But it must not be forgotten that this very fact testifies of the great intrinsic

richness of the soil in mineral plant food, and of the highly profitable results sure to follow the effectual reclamation of these low-lying alkali tracts.

The alkali salts vary in composition, but usually consist of three principal ingredients, whose relative proportions vary materially in different regions, and cause corresponding differences in the effects on vegetation, whether natural or cultivated. These three ingredients are, in the usual order of their abundance, common salt (sodium chloride), Glauber's salt (sodium sulphate), and salsoda (sodium carbonate). The latter is sometimes present in predominant quantity, and then gives rise to what is popularly known as "black alkali," from the fact that the sodium carbonate forms with the humus of the soil a dark-colored solution, which on evaporation in mud-puddles leaves black rings on the soil surface. The distinction between the "black alkali" and the "white," consisting mainly of the bland and relatively innocuous Glauber's and common salt, is important, for the effect of carbonate of soda upon vegetation many times more injurious than that of the former, not only because of its direct corroding effects upon the root-crown when it accumulates near the surface, but also because, as already stated, it dissolves out of the soil that highly important ingredient, humus or vegetable mold, and, moreover, renders clayey soils almost completely untillable. The latter effect is well seen in the low-lying alkali spots, where (even in the sandy lands) the soil, in which the clay accumulates, is so obstinately caked together as to render it extremely difficult to put in the plow, and comes up in heavy intractable clods most difficult to break up. The latter difficulty does not exist in the case of the "white" alkali soils; they till kindly and the only trouble lies in the accumulation of the salts at the surface, in consequence of evaporation, to such extent as to injure the surface roots and root crown. Carbonate of soda or "black" alkali is converted into the "white" (i. e., Glauber's salt) by dressings of gypsum or land-plaster, and the relief thus afforded is in very many cases all that is needed to insure profitable cultivation.

It is only in exceptionally bad cases that enough of any of these soluble salts to injure the deeper roots exists in the depths of the soil, or within more than one inch of the surface. This surface accumulation is obvious enough to the eye during the dry season; it is well illustrated by the examination of the soluble contents of a soil from Fresno county, given first in the table below. It will be seen that at the surface the alkali contents were nearly four times as great as at any point below.

Aside from the three most prevalent ingredi-

ents of the alkali crusts, there are always present a number of others, some of which are of fundamental importance to plant life, and of which the mere presence in the soluble form proves that the soil contains, in a more or less insoluble shape but still accessible to the use of plants, all that it can retain of these useful ingredients. Such are particularly the salts of potash, and soluble phosphates, both of which are very commonly found in the alkali salts from the heavier soils of the San Joaquin valley; while saltpeter in the form of both potassium and sodium nitrates is common especially in the "black" alkali districts, and represents a surplus of the most expensive of the fertilizers which the farmer finds it necessary to supply to his soils in order to maintain their productiveness. While it is true that these nitrates are not retained by the soil but pass away with the drainage, their presence testifies of the intensity of the nitrifying process in the soil under the conditions of the local climate.

Thus, while the presence of an excess of alkali salts is an evil, requiring to be abated, yet the above facts, as well as the results of actual trial, prove that alkali soils are eminently worthy of attention and corrective treatment because of their great intrinsic resources in plant food.

The most obvious mode of correcting the condition of alkali soils generally is, clearly, to supplement by artificial means the natural deficiency of drainage through the soil, resulting from the scanty rainfall. For, if we once leach out the surplus salts that have accumulated for ages, it will take ages to bring about the same condition of things, and we shall practically have put an end to the "alkali" difficulty.

But this leaching-out cannot be done by putting water on the surface of the land, unless at the same time its removal after passing through the soil is provided for. For it is manifest that if the alkali solution descends no farther than the subsoil and remains there, ready to reascend so soon as evaporation at the surface calls for it, we shall have done no good. In fact, the inutility of this mode of procedure has been so thoroughly tested in practice, both in California and in India, as to have shown that it is the reverse of useful and increases instead of diminishing the evil; because the soluble salts thereafter ascend from greater depths than the annual rainfall could have reached, and their sum total is thus materially increased. This is the simple explanation of what is known in the Great Valley as the "rise of the alkali," which is observed in all lands subjected to surface irrigation for a some length of time; creating increasing inconvenience and alarm as time progresses.

While under the natural conditions existing in California there is no real cause for alarm so far as the ultimate repression of the alkali-plague is concerned, and while in the majority of cases judicious cultivation (with the use of gypsum when called for) is capable of preventing any serious damage to crops, yet the present inconvenience and loss resulting from the rise and rapid extension of the alkali-area are sufficient to call for strong measures toward the abatement of the evil. The first condition of such abatement is a general understanding of the nature and causes of the trouble, the more

as in many cases the improvement cannot be brought about without such concerted action (and perhaps even the exercise of the right of condemnation and eminent domain) as is required in the case of irrigation works.

UNDERDRAINAGE is the general and absolute corrective for alkali. To flood the land until underdrains laid reasonable distances apart shall have run for some time, will end the trouble, not only for the time being but for centuries; provided only that solid beds of the alkali salts do not underlie, as unfortunately seems to be the case in some of the lower lands of the upper Tulare basin. How to deal with that state of things need not now be discussed, as it is the rare exception.

In the porous soils of the Fresno neighborhood, where until quite lately alkali was unknown, its rise has clearly been brought about by the rise of the water-table, resulting from the establishment of high-lying ditches; and its abatement can be brought about by the same means that have been used for lowering the water itself, that threatened to swamp the very plains that 15 years ago showed no moisture at the depth of 40 or more feet, but where a few years ago water was within two or three feet of the surface, drowning out both vines and trees. The establishment of drainage-ditches has put an end to this danger wherever it has been properly carried out, and with it the alkali trouble can also be terminated, by thorough flooding of the surface until the ditches shall have carried away the leachings into the country drainage.

There is, however, in certain regions one difficulty in the way of the success of this operation, namely, the existence of a bed or layer of calcareous hardpan, equally impervious to roots and water. Farmers have already learned that where this hardpan underlies the subsoil at a few feet depth, trees and vines will not flourish unless it is broken through, so as to enable the roots to pass beneath. This "knocking the bottom out" of the holes in which trees are to be planted has already become a well-understood operation in the hardpan neighborhoods, the crowbar, or even a charge of powder being called into requisition. It is noticeable that in such localities the alkali plague comes soonest and is most persistent, being the natural result of the retention of the alkaline water above the hardpan layer, and its re-ascent, with all its salts, so soon as evaporation sets in. The hardpan areas are generally basin-shaped; with the rise of the irrigation water the latter, with the salts it has leached out of the substrata of the soil, will come in around the edges or through the cracks of the hardpan mass, and remaining there despite of drains, will bring an increasing amount of alkali to the surface each successive year, until spots of a few square yards grow into many acres and finally become a serious menace to the welfare of the trees and vines.

The obvious remedy in such cases is to make the drainage ditches deep enough to cut through the hardpan, and to knock so many holes into the latter as to facilitate drainage to the necessary extent.

It may be objected that this is too costly; and probably there are cases in which this will be so. It then behooves the owner to consider the choice between a change of location, and

the adoption of other crops and repression of the alkali by careful cultivation and the use of gypsum, as set forth in the pamphlet on the subject heretofore published by this department. But the time is not far distant when in California as well as in Illinois and in the East generally, the laying of underdrains will be considered an excellent investment on any land as valuable as all irrigated land is likely to be; and when that day comes, "alkali" will be at an end on irrigated lands in this State.

In the table below are given the results of a number of examinations of alkali soils made within the present year, as well as some of earlier date and heretofore published, which illustrate well the variability of the composition of the soluble salts within short distances. Thus, within the ten acre limits of Miss Austin's place in Central Colony, Fresno, we have two samples of quite different composition; one (No. 1) of the "white," the other of the "black" type, viz., consisting chiefly of carbonate of soda. In the next three columns we find the alkali of the "white" type, while again, that from the Emigrant Ditch is very "black" and is almost free from Glauber's salt. In Tulare county carbonate of soda is quite generally present in large proportion, doubtless in consequence of the more general prevalence of heavy soils rich in vegetable matter, which promotes the formation of the carbonate. Yet while (according to former observations not recorded here) this is true of the alkali of the Mussel-slug country nearest the streams, the alkali around Hanford is (or was in 1880) almost exclusively of the "white" type. While the water of Tulare lake, as shown in a former bulletin, is rich in the carbonate, extensive tracts south of the lake, and which were doubtless covered by its waters at a time not very remote (Smyrna neighborhood, in townships 25 and 26, range 23), prove to contain mere traces of that substance in their alkali, and do not require the use of gypsum. [See next page.]

It is thus apparent that so far as the efficacy of the use of gypsum is concerned, each region will have to determine for itself whether or not its alkali is of the black or white type; and as this can be generally readily ascertained by a simple inspection of puddles on alkali ground—whether or not tinted by the dissolution of the vegetable mold into an inky liquid leaving black rings on evaporation—no one need be long in doubt on that point. Wherever the black tint appears, dressings of land plaster, ranging from 200 to 500 pounds per acre, will usually effect the change from "black" to "white," after one or two irrigations followed by cultivation; preventing the killing of seeds in the ground as well as the dwindling of seedlings after sprouting, and greatly improving the tillage of the heavier soils. Thereafter, the chief measure toward the prevention of the rise of the salts to the surface is whatever tends to prevent evaporation from the land surface; and therefore particularly the maintenance of deep and thorough tilth, and the avoidance of the formation of any surface crusts. These means, together with a proper choice of crops and mode of culture, will serve to maintain good production in most cases until the radical cure by *drainage alongside of irrigation* shall be justified by the increased value of the land.

TABLE SHOWING COMPOSITION OF ALKALI SALTS IN SAN JOAQUIN VALLEY.

FRESNO COUNTY.											
Sections 13 and 24 T. 14 S. R. 19 E., 4 miles S. W. from Fresno.						Miss Austin's Ranch, Central Colony.		N. W. Cor. N $\frac{1}{2}$ Sec. 20 T. 14 S. R. 21 E.		Easton.	Emigrant Ditch.
Alkali soil 1888.	Alkali Spot, 1889.				Surface soil. No. 1	Surface soil. No. 2.	Surface soil.	Surface soil.			
	1 inch, surface.	18 inches below surface	26 inches below surface.	42 inches hardpan.							
Soluble salts in 100 parts soil.....	0.76	0.20	0.18	0.16	3.54 small	1.90 moderate small	1.20	2.69			
Potassium sulphate.....											
*Potassium nitrate.....											
Potassium carbonate (Saleratus).....											
Sodium sulphate (Glauber's salt).....	large	small	small	very slight	large	large	much	moderate	large		
Sodium carbonate (Sal-soda).....	very slight	large	small	large	small	chiefly	small	small	large	chiefly	
Sodium chloride (Common salt).....	chiefly	moderate	chiefly	moderate	chiefly	large	chiefly	chiefly	large	little	
*Sodium phosphate.....											
Calcium sulphate (Gypsum).....	moderate	small	very slight	very slight	small	moderate small	small	small	much		
Magnesium sulphate (Epsom salt).....									much		
Organic matter.....											

*Very generally present, but not always in quantities sufficient for determination.

	TULARE COUNTY.						KERN COUNTY.									
	Goshen.	People's Ditch.	Near Lake Tulare.	Visalia.	Lemoore.	Tulare Exp't Station.	Alkali crusts from the San Joaquin artesian belt, Townships 25 and 26 R. 23 E. W. S. W. from Delano, S. P. R. R.								Sumner.	Kern Island.
	Surface soil.	Alkali crust.	Surface soil.	Surface soil.	Alkali crust.	Alkali crust.	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	Alkali crust.	Alkali crust.
Soluble salts in 100 parts soil.....	1.40		.83	1.26												
Potassium sulphate.....						small										4.72
*Potassium nitrate.....						small										
Potassium carbonate (Saleratus).....				18.80												
Sodium sulphate (Glauber's salt).....	44.24	1.92	31.30(n)	13.4	chiefly	32.8	small	moderate	moderate	moderate	large	small	small	small	19.20	70.61
Sodium carbonate (Sal-soda).....	32.98	88.09	18.2	45.3		36.16										14.82
Sodium chloride (Common salt).....	16.74	1.00		4.4	little	31.16	large	moderate	large	large	small	large	small	large	37.14	4.13
*Sodium phosphate.....	1.97		0.22	10.4												
Calcium sulphate (Gypsum).....					little		small	small	small	small	small	small	small	small	0.96	0.08
Magnesium sulphate (Epsom salt).....				8.1	moderate		small	small	small	small	small	small	small	small	18.31	
Organic matter.....	1.57	9.21	7.5			5.37									20.87	

*Very generally present, but not always in quantities sufficient for determination. (n) Common and Glauber's salts.